

# Research-based spin-offs as agents of knowledge dissemination: evidence from the analysis of innovation networks

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## Research-based spin-offs as agents of knowledge dissemination: evidence from the analysis of innovation networks

### ABSTRACT

The paper addresses the role played by research-based spin-offs (RBSOs) as knowledge dissemination mechanisms, through their position in knowledge networks. For this purpose the paper analyses the formal networks established by Portuguese RBSOs, in the context of publicly funded research, technology and pre-commercial product development projects, and investigates their configuration across two levels. At organisational level, in order to understand whether RBSOs extend their reach beyond the academic sphere; and if they do, whether they connect to organisations located downstream in the knowledge value chain, and which is their position in networks involving both research organisations and other firms. At spatial level, in order to understand whether RBSOs extend their reach beyond the region where they are created, thus potentially acting as connectors between diverse regions. The analysis starts from the population of RBSOs created in Portugal until 2007 (327 firms) and identifies those that have established formal technological relationships, as part of projects funded by all the relevant programmes launched in the period 1993-2012. As a result, the analysis encompasses 192 collaborative projects and involves 82 spin-offs and 281 partners, of which only 20% are research organisations, the remaining being other firms and a variety of other downstream organisations. The results, although still preliminary, provide some insights into the knowledge networking behaviour of the RBSOs. As expected, research organisations are a central actor in spin-offs' networks, being the sole partner for some of them. But half of the RBSOs have moved beyond the academic sphere, being frequently a central element in tripartite technological relationships between research and other organisations, and occupying an intermediation position in the network, thus potentially acting as facilitators in knowledge circulation and transformation. Also as expected, RBSOs are predominantly located in the main metropolitan areas and tend to relate with organisations similarly located. But while geographical proximity emerges as important in the choice of partners, in about half of the cases, RBSOs knowledge networks have extended beyond regional boundaries. Given their central position in the network, this suggests a role as connectors across regions that will be explored in subsequent research.

**KEYWORDS:** spin-offs; knowledge networks; space; knowledge dissemination; inter-firm relationships.

## 1. INTRODUCTION

In the last decades universities have increasingly been engaged in technology transfer activities, introducing a variety of policies to encourage and support the initiatives of their staff and students. Among these activities assume particular relevance the creation of research-based spin-off firms (RBSOs), which are regarded as generating value from academic research and, simultaneously, contributing to increase universities' reputation (Mustar et al, 2008; Perez and Sanchez, 2003; Wright et al, 2007).

The extension of the spin-off phenomenon, first in the US and then in Europe, led to the emergence of a stream of literature that addressed these firms' particular characteristics, namely the science-based nature of the knowledge being exploited, the close relationship with the parent organisation, and firms' internal features, such as the high scientific skills of the human capital and a frequent absence of business capabilities and experience (Djokovic and Souitaris, 2008; Helm and Mauroner, 2007; Mustar et al, 2006; Phan and Siegel, 2006).

More recently research has turned to the impact of RBSO on economic development, in particular at a regional level (Bathelt et al, 2010; Buenstorf and Geissler, 2011). However, it can be argued that RBSOs effective impact is not likely to be fully captured by traditional indicators such as employment or turnover. Given the nature of their activities and the intermediate position they often occupy between academic research and the market (Autio, 1997; Fontes, 2005), RBSOs impact is more clearly expressed through the value they create in knowledge and innovation networks, as agents of knowledge acquisition, transformation and diffusion (Harrison and Leitch, 2010; Perez and Sanchez, 2003; Walter et al, 2006).

While this distinctive function of RBSOs is acknowledged in the literature, empirical research on RBSOs performance, beyond the creation process, is still limited. Moreover, research tends to focus on the relations between RBSOs and the "parent" (or other research organisations) (Heblich and Slavtchev, 2013; Semadeni and Cannella, 2011) and to put special emphasis on firms regional embeddedness and influence (Huggins and Johnston, 2009; Breznitz et al, 2008). But much less is known regarding RBSOs knowledge interactions with other firms, directly or as intermediaries from other knowledge sources; and on their role as knowledge conveyers across regions.

The objective of this paper is to address this gap, contributing to understand whether RBSOs are effectively acting as knowledge dissemination mechanisms, through their position in knowledge networks, and which is the reach of their activities. For this purpose, the paper investigates the knowledge networks established by RBSOs, at two levels. At organisational level, to understand whether firms extend their reach beyond the academic sphere; and if they

do, whether they reach to organisations located downstream in the value chain, thus potentially performing a wider role as knowledge disseminators. At spatial level, to understand whether firms extend their reach beyond the region where they are created, thus potentially acting as connectors between diverse regions.

For this purpose we conduct an analysis of the formal knowledge networks established by Portuguese RBSOs in the context of collaborative research, technology and product development projects, between 1993 and 2012. The data encompasses the known population of RBSOs created in Portugal until 2007 and all the relevant Portuguese funding programmes. The analysis addresses the configuration of the formal knowledge networks formed in the context of these projects, focusing on partner *composition* and *location*, in order to assess RBSOs' organisational and spatial reach (overall and for specific industries). The results provide some indications towards the extent and nature of RBSOs knowledge impacts.

## **2. FROM ACADEMIA TO INDUSTRY – THE ROLE OF SPIN- OFFS**

Research-based spin-offs have been found to play an important role as knowledge transfer mechanisms (Bathelt et al, 2010; Helm and Mauroner, 2007). In fact, RBSOs are set-up to commercially exploit the results of academic research, transforming it in technologies, products or services and making them accessible to the society. Moreover, if successful in their endeavour, RBSOs are likely to continue acting as sources and disseminators of new knowledge over time.

### ***2.1 The nature of RBSOs technological relations: “bridging” between organisations?***

For analytical purposes it is possible to consider two main stages in the transfer process enacted by RBSOs. One stage that involves the interaction between the research organisation and the new firm, to support the further development of the knowledge that is being commercialised as part of the spin-off process; or to joint-develop new or complementary knowledge in areas relevant for the firm. Another stage that involves the search for and interaction with potential users of the technology or its applications, in order to gain a better understanding of market needs and requirements; and/or to gain access to complementary competences and resources. Although relationships with users are more frequently related with business and market development, they may also concern the development of new technological knowledge in areas that are critical for the success of the innovation and that go beyond the spin-off frequently specialised competences (Colombo et al, 2006).

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These stages can overlap, i.e. these processes may take place simultaneously in the context of tripartite relationships that involve research organisations, spin-offs and other firms. Research conducted on this type of alliance has found evidence of a certain division of work between these actors (Stuart et al, 2007). For instance, Hess et al (2013), based on a series of case studies, concluded that in alliances between spin-offs, industry and academic partners, the members had well-defined roles in the innovation process. In fact, product needs, access to markets and industrialisation ability were brought into the alliance by the industry partner, while the spin-off delivered the agility and speed connected to in-depth deep technology know-how, plus its academic network, providing access to laboratories and relevant technology expertise.

The effectiveness of RBSO as a "bridge" between academia and the industry depends on entrepreneurial actions, such as opportunity identification, risk taking, resource mobilisation that can be more effectively achieved through networks (Grandi and Grimaldi, 2003; Walter et al, 2006). The capacity to establish external networks is presented as a competitive advantage of new high-technology firms, supporting the discovery of opportunities, the access to a variety of resources and collaborative learning with partners (Elfring and Hulsink, 2003; Grandi and Grimaldi, 2003; van Geenhuizen et al, 2014).

However, despite the extensive literature on the role of networks in technological entrepreneurship (Elfring and Hulsink, 2003; Slotte-Kock and Coviello, 2010) there is still limited research on the nature of the relationships that are established as part of the bridging process potentially conducted by RBSOs. At this level, the literature tends to focus on the interaction between the spin-off and the parent organisation (Audretsch and Lehmann, 2005; Colombo et al, 2006; Heblich and Slavtchev, 2013; Semadeni and Cannella, 2011), giving much less attention to the downstream relationships established with other types of organisations, to further develop and commercialise the technology. Among these, technological relationships - that is, those concerned with completing the development of technologies that are often in a very incipient stage, or with the definition of product and/or process requirements and with product development, prior to commercialisation, which are likely to require a set of technological competences located downstream from academic research (Autio, 1997) - are particularly absent, despite their relevance for this type of firm (Conceição et al, 2012).

It is nevertheless relevant to point out that the need for and intensity of the technological relationships, and the composition of resulting knowledge networks can vary between firms. In fact, it has been shown that the patterns of interaction between academy and industry depend on the scientific fields (Schartinger et al, 2002). It has also been shown that the innovation process, and thus the type of knowledge and knowledge exchanges required to achieve it, are strongly shaped by firms and industries specific knowledge bases (Asheim and Coenen, 2005; Plum and

Hassink, 2011). As a result, the configuration of knowledge networks established by new technology intensive firms was found to differ between industries (Salavisa et al, 2012). These differences are likely to be pertinent in the case of RBSOs, which are not necessarily a homogeneous group (Cunha et al, 2013), affecting both the relevance of a continued collaboration with research organisations, and the intensity and type of technological relationships they establish with downstream organisations.

Considering the above, it is possible to raise the following research questions, in what concerns the composition of the knowledge networks established by RBSOs.

- a. Are technological relationships mostly established with the parent research organisation, or do they also involve other organisations located downstream?
- b. When networks involve other organisations are RBSO mostly part of tripartite relationships, also involving research organisations?
- c. Are these knowledge networks more frequent in some industries / technology fields?

## ***2.2 The location of RBSOs partners: connectors between regions?***

RBSOs tend to be located in clusters, usually in large cities with a high business concentration, thereby benefiting from agglomeration economies, i.e. positive externalities resulting from co-location (Audretsch and Feldman, 2004; Buenstorf and Geissler, 2011). Location in metropolitan areas also reflects the importance assumed by the proximity to major universities in gaining access to knowledge spillovers, which is often facilitated by the personal networks of academic entrepreneurs (Conceição et al, 2014; Heblich and Slavtchev, 2013; Asterbo and Bazzazian, 2011; Shane, 2004). In fact spin-offs tend to locate in the vicinity of the parent organisations, with which they often retain close relationships, at least in the early years (Lemarie et al, 2001; Kolympiris, 2015).

Overall, RBSOs location in metropolitan areas favours the development of a wider network of relationships, which positively influences their performance (Audretsch and Feldman, 2004; Capello, 2006). For instance, van Geenhuizen et al (2014), comparing the spin-offs population of two universities located in different environments, found that those located in metropolitan areas benefit from a more diverse network than those in more isolated cities. The heterogeneity of the networks (e.g. demographic, geographical and management diversity) has also been found to have a positive effect on knowledge transfer (Cummings, 2004). However, less attention was paid to an eventual cross-regional scope of these networks, in particular to whether RBSOs, which tend to be located in areas with greater knowledge concentrations, connect to organisations located in other regions.

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Considering the above, it is possible to raise the following research questions in what concerns the spatial reach of the knowledge networks established by RBSOs.

- a. Are RBSO knowledge networks more frequently composed of organisations located in the main metropolitan areas?
- b. Do RBSOs establish technological relationships preferably with organisations located in the same region?

### 3. DATA AND METHOD

#### 3.1 Data sample: the Portuguese RBSOs

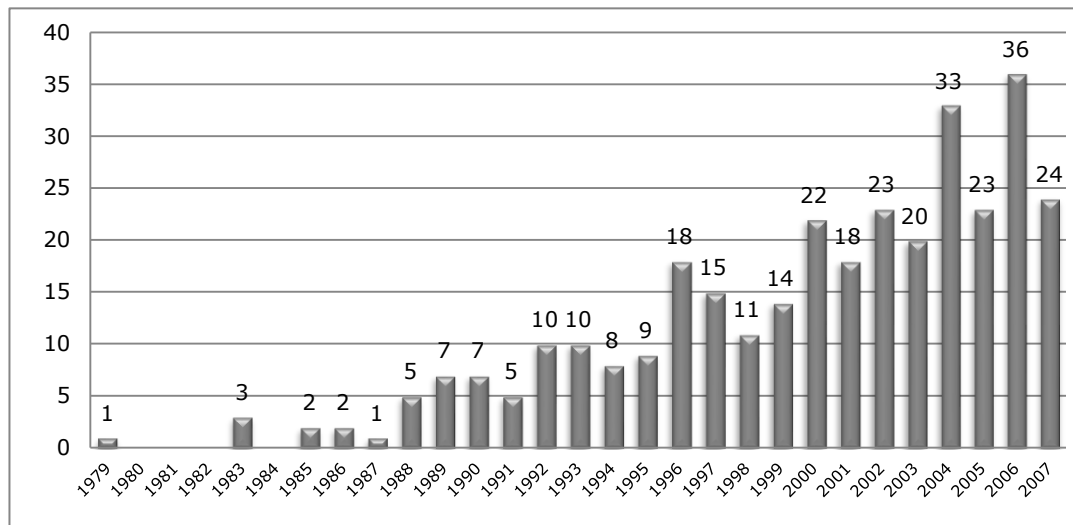
The analysis uses a self-collected dataset composed of the known population of RBSOs created in Portugal until 2007, totalling 327 firms. Although there is not, in the literature, a single definition of the concept of academic or research-based spin-offs, it is possible to describe them as firms whose creation is based on the formal and/or informal transfer of knowledge or technology generated in public research organisations (Djokovic and Souitaris, 2008; Mustar et al., 2006; Pirnay et al 2003). For this study we considered firms created by entrepreneurs who have some stable connection with a university or other research institution - such as faculty members, researchers and graduate students - and who are applying knowledge obtained or technology developed as part of their research activity; and firms created by external entrepreneurs based on the transfer of technology developed by a research organisation (Conceição et al, 2014).

The first firm identified was created in 1979, but the number of spin-offs only started to increase in the 1990s, effectively taking off in the 2000s: 54.1% were created after 2000 (Figure 1). As expected, these firms tend to be formed in the main metropolitan areas where the most prestigious research universities are also located. In fact, 52% of the spin-offs are located in municipalities belonging to the districts of Lisbon (the capital, with 30%) and Porto (the second city, with 22%) followed at a certain distance by the districts of Coimbra, Braga and Aveiro (Figure 2) (Conceição et al, 2014).



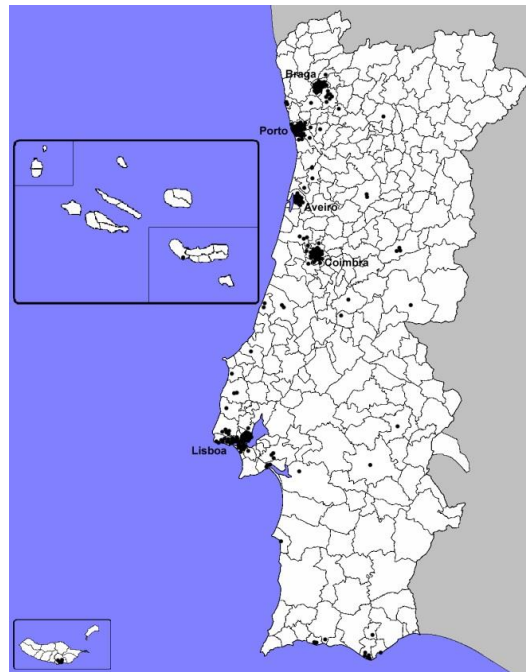
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**Figure 1- Number of Portuguese RBSOs by founding date (1979-2007) (n=327)**



Source: Own calculations.

**Figure 2 – Spatial distribution of Portuguese RBSO per municipalities**



Note: Each dot = 1 spin-off firm. Source: Own calculations.

### 3.2 Knowledge networks: data and analysis

To identify the formal knowledge networks established by the RBSOs, the paper draws on data on collaborative projects conducted in Portugal in the context of all public programmes that funded research and pre-competitive technology and product development and/or demonstration activities. Given RBSOs reliance on public funding for research and development activities (Wright et al,

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2007), this data is expected to offer a good coverage of the formal technological relationships established these firms in this domain.

The data was obtained from the Innovation Agency (AdI) database<sup>1</sup> and covers the period 1992-2012. All collaborative projects with spin-off involvement were identified, totalling 192 projects (see Appendix 1). Data was collected (in March 2015) on the characteristics of each project and on the partners involved<sup>2</sup>. The data was treated in order to harmonize organisations' names (e.g. the same organisation appears named by its acronym and by its full name). Then, the organisations were characterised along three dimensions: location, type and area of activity. RBSOs were also classified according to the industry where they conducted their principal activity. The "parent" research organisations of the RBSOs were identified and their presence in the same project of their spin-offs was signalled.

Only 82 of the 327 Portuguese spin-offs had established collaborative relationships in the context of these projects. The 192 projects identified involved 215 participations by RBSOs. The vast majority of the firms identified (82%) participated in 1 to 3 projects. Two spin-offs, both in the ICT industry and originating from the same university (University of Coimbra), had a disproportionately high number of participations (respectively 17 and 21 projects).

In order to analyse the structure of technological collaborations enacted by the RBSO, we built the knowledge network formed by the participants in these projects. Collaborative projects constitute two-mode networks that link organisations to an event - the projects. From these we have extracted a one-mode network, considering inter-organisational networks, where a tie joins two organisations, if they collaborate in the same project. We have built symmetric adjacency matrices, valued by the number of common projects and conducted Social Network Analysis (SNA), using UCINET software. The diagrams were obtained with NetDraw software.

From the vast set of SNA measures we will focus our attention on: i) the size of the network, in terms of number of actors and ties; ii) the network composition, in terms of the share of each type of partner; iii) the positioning of actors, assessing their centrality and their role as cut-points. Centrality measures enable to detect more favourable network positions, namely in terms of access to the most relevant knowledge sources (Powell et al, 1996). In this paper two different centrality measures are used: degree centrality and betweenness centrality. Degree centrality corresponds to the number of direct relations each actor has in the network. It enables to capture those actors that have a large number of innovation partners, thus being more active in the network, either because they are involved in a large number of projects and/or in projects with numerous partners. Betweenness centrality is

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<sup>1</sup> Free access database found in <http://projectos.adi.pt/>

<sup>2</sup> The database provides data on the following items: *Project*: Title & Summary, Technological field, Application sector, Funding programme, Amount of funding, Start date; *Partners*: Name, Location and indication of Coordinator.

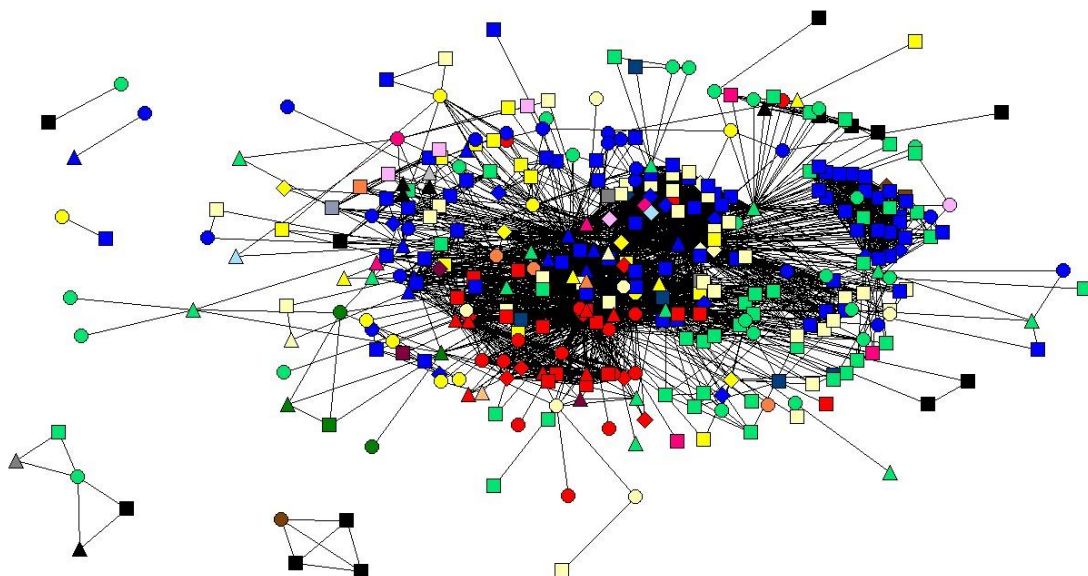
calculated as the share of shortest paths between other organisations that pass through the focal actor. Therefore, it enables to capture these actors that lie between various other organisations, thus occupying a favourable position in terms of influence over the information flow in the innovation network (Gilsing et al, 2008). The cutpoints in the networks were also identified. If a cutpoint actor is removed from the network it will become divided into disconnected groups. Therefore, cutpoints are actors that have a pivotal significance in holding the network together (Scott, 2000) and may act as brokers among otherwise disconnected groups.

## 4. PORTUGUESE RBSO KNOWLEDGE NETWORKS

### 4.1 Network composition and the role of actors

The RBSO knowledge network is represented in Figure 3. The network consists of 363 organisations, of which 23% are RBSOs, 14% are research organisations (ROs) (including universities and independent research centres, both public and private non-profit), 55% are other firms and 8% are a variety of other organisations (labelled "Others"), with a predominance of business associations, government departments, regional agencies and other collective organisations (Table 1). For analytical purposes the group "Others" was included in the group "Other firms", since conceptually both are technology users, i.e., downstream organisations. The network is formed by a large component (involving about 96% of the network actors and 94% of the RBSO) and by five small components that reflect the individual networks of five RBSOs.

**Figure 3: Portuguese RBSO knowledge network (1993-2012)**



**Legend:** Shapes represent organisation type: Spin-offs - circle; Other firms - square; Research org - triangle; Others - diamond. Colours represent organisation location (district): Lisboa - Light green; Porto - Blue; Coimbra - Red; Braga - Yellow; Aveiro - Light yellow; Beja - Purple; Bragança - Light orange; Castelo Branco - Orange; Évora - Light blue; Faro - Green; Leiria - Dark blue; Santarém - Light pink; Setúbal - Pink; Viana do Castelo - Violet; Vila Real - Light grey; Viseu - Dark grey; Madeira - Brown; Foreign - Black.

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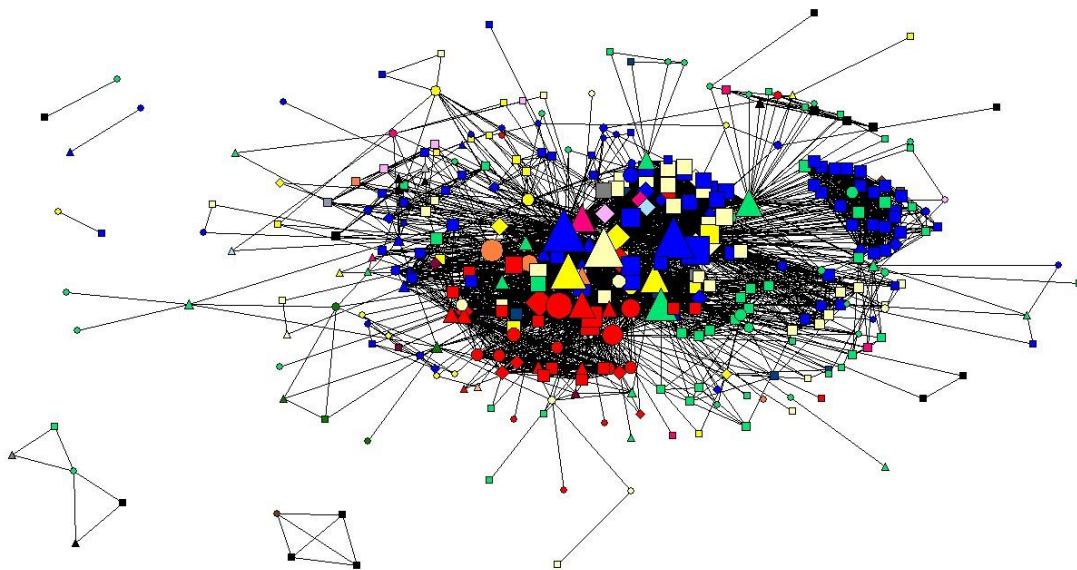
**Table 1 - Distribution of Partners by type**

Partners	Number	Percentage
Spin-offs	82	22.59
Research organisations	52	14.33
Other firms	199	54.82
Others	30	8.26
Total	363	100.00

**Source:** Own calculations.

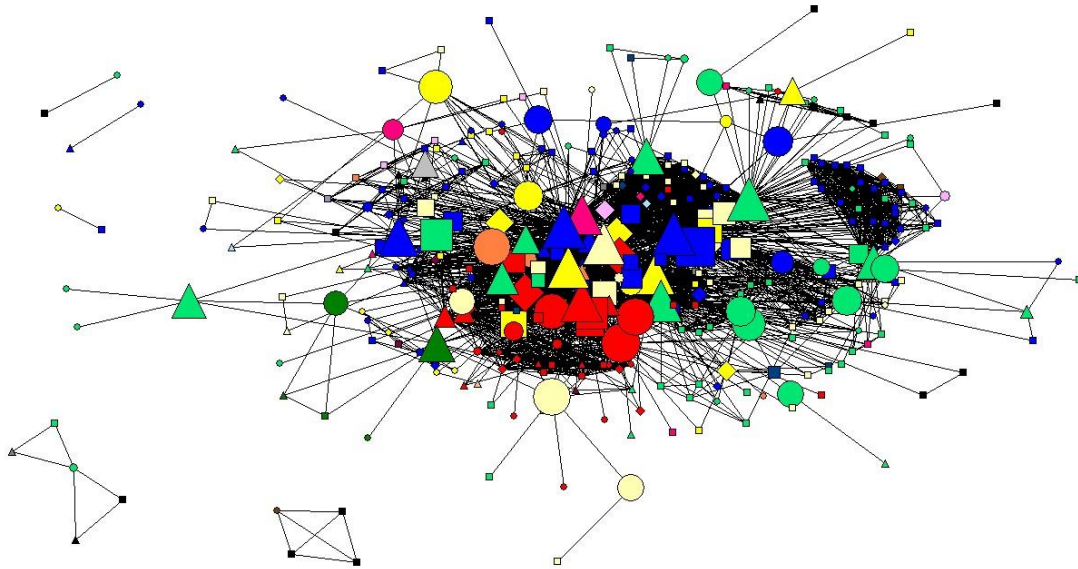
A detailed analysis of the 192 formal technological collaborations reveals that in half of the projects the spin-offs established partnerships exclusively with ROs (Table 2). Among these, “Parents” have a prominent role: in half of the projects the RBSO parent is involved in the collaboration and in  $\frac{1}{4}$  the RBSO only collaborates with its parent. As would be expected, research organisations are important actors in the network. In fact, more than  $\frac{3}{4}$  of the projects involve at least one RO and, despite their relatively low share in the total number of individual network actors (14%), they occupy very central positions in the network, both in terms of degree and in terms of betweenness (Figures 4 and 5).

**Figure 4: Actor degree centrality**



**Legend:** Identical to Figure 3. The size of the node reflects the actor centrality.

**Figure 5: Actor betweenness centrality**



**Legend:** Identical to Figure 3. The size of the node reflects the actor centrality.

**Table 2: Distribution of teams – projects composition**

Team	Number	Percentage
Spin-offs + ROs	96	50.00
Spin-offs + Other firms	33	17.19
Spin-offs + ROs+ Other firms	63	32.81
Total	192	100.00

**Source:** Own calculations.

The data also shows that RBSOs collaborate exclusively with other firms in only a small number of projects (17%). But, in almost one third of the projects there is a tripartite network, which includes spin-offs, research organisations and other firms (Table 2). This result points to an intermediation role played by the RBSO in the network, which is further corroborated by the fact that the RBSO is the coordinator in over  $\frac{3}{4}$  of the projects. The same conclusion can be drawn from the analysis of betweenness centrality (Figure 5), where spin-offs (represented by circles) emerge as relevant actors. Two RBSOs appear in the betweenness centrality top 10 (Table 3), and if we consider the first decile of the betweenness distribution, we observe that  $\frac{1}{3}$  of the most central actors are RBSO. As mentioned above, organisations with a high betweenness centrality appear frequently in the path between other organisations, thus enabling the circulation of knowledge between them and having some potential control over the knowledge/information flow. Moreover, RBSO emerge as the most frequent type of organisation in the analysis of cutpoints (Figure 6): half of the cut-points are RBSO, the



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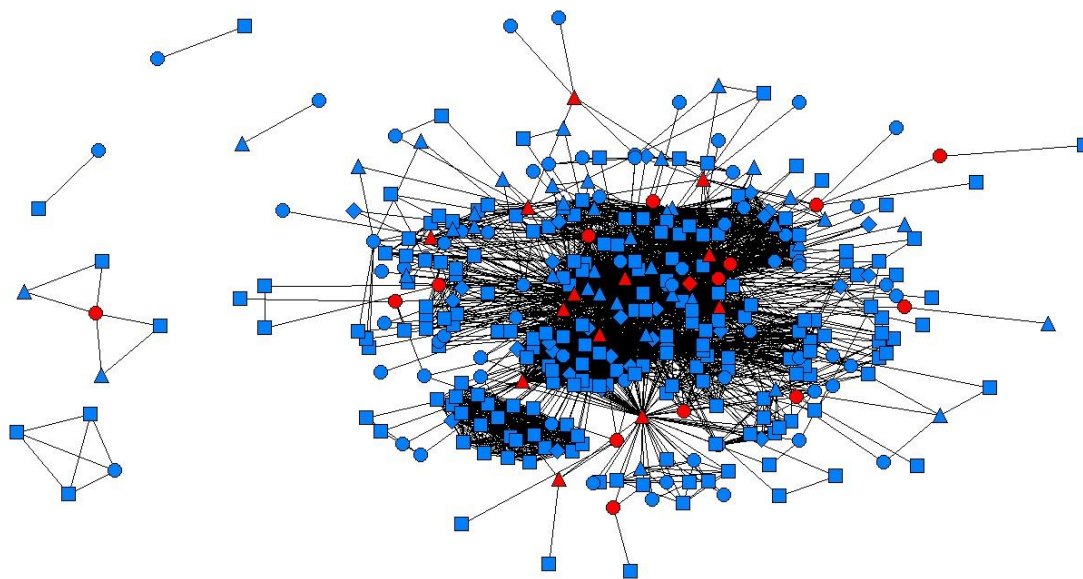
remaining half being (unequally) divided by research (46%) and other (4%) organisations. This means that RBSO seem to occupy a relevant role in this network, both structuring it and facilitating knowledge/ information diffusion.

**Table 3:** Most central organization in terms of betweenness

Organization	Type
INESC Porto	Research organisation
INESC	Research organisation
University of Minho	Research organisation
University of Porto	Research organisation
Critical Software	RBSO
EFACEC	Other firm
INEGI	Research organisation
NOVA	Research organisation
Plux	RBSO
University of Aveiro	Research organisation

**Source:** Own calculations.

**Figure 6:** Network cutpoints



**Legend:** Shapes represent organisation type: Spin-offs - circle; Other firms - square; Research org - triangle; Others - diamond.

Nodes in red represent the cut-points.

Regarding the industry, the majority of collaborative projects identified involve RBSOs in biotechnology or in information & communication technologies (ICT) (Table 4). However, considering the distribution of spin-offs' population, it is possible to conclude that technological relationships are more frequently present among electronics firms and biotechnology firms

(respectively 47% and 36%). They are relatively less frequent<sup>3</sup> among ICT and energy firms and almost inexistent in the remaining group.

**Table 4- Distribution of Portuguese RBSOs with formal networks by Industry**

Sector	Spin-offs with formal networks		Spin-offs Population		Relative frequency
	N.º	%	N.º	%	
Biotechnology	23	28.05	64	19.57	35.94
Energy & Environment	7	08.54	41	12.54	17.07
Electronics	16	19.51	34	10.40	47.06
ICT	30	36.59	133	40.67	22.56
Others <sup>1</sup>	6	07.31	55	16.82	10.91
Total	82	100.00	327	100.00	

**Others include:** Engineering and High-tech services. Source: Own calculations.

The technological area of the project was also found to influence the nature of the relationships established. In fact, the involvement of the parent organisation was relatively more frequent in the case of chemicals, biotechnology, agro-food and materials and relatively lower in the other areas, in particular in ICT and electronics. Similarly, in what concerns relationships with downstream partners, it was found that tripartite networks are relatively more frequent in projects in the agro-food, materials and automation areas and almost absent in biotechnology and chemicals. Relationships exclusively with firms are again more frequent in agro-food and materials, but also in ICT and energy & environment. This suggests differences between RBSOs active in different industries, both regarding the need to establish relationships and the nature of the knowledge that is exchanged in these relationships (Salavisa et al, 2012).

#### **4.2 The localisation of actors**

The results show that spin-offs located in metropolitan areas establish formal technological relationships more frequently (Table 5). Between 25 and 30% of the spin-offs located in the 5 main districts participated in collaborative projects, as compared with 16% of the spin-offs located in those with lower population density. Furthermore, when we analyse the location of the other organisations involved in the 82 projects, we conclude that it is equally in these districts – particularly Lisboa and Porto – that RBSO partners are predominantly located (Table 6).

<sup>3</sup> Relative frequency = (Number of Spin-offs with formal networks / Number of Spin-offs Population) \* 100

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**Table 5: Distribution of Portuguese RBSOs with formal networks by localisation**

Location (district)	Spin-offs networks	with	formal	Spin-offs Population		Relative frequency
	N.º		%	N.º	%	
Lisboa	25		30.49	99	30.28	25.25
Porto	20		24.39	71	21.71	28.17
Coimbra	14		17.07	50	15.29	28.00
Braga	9		10.98	38	11.62	23.68
Aveiro	6		07.31	19	05.81	31.58
Others <sup>1</sup>	8		09.76	50	15.29	16.00
Total	82		100.00	327	100.00	

<sup>1</sup> Others relate to 12 Districts with less than 8 partners. **Source:** Own calculations

**Table 6: Distribution of network partners by localisation**

Location (district)	Number	Percentage
Lisboa	77	21.21
Porto	108	29.75
Coimbra	43	11.85
Braga	31	08.54
Aveiro	44	12.12
Others	42	11.57
<i>Foreign</i>	<i>18</i>	<i>04.96</i>
Total	363	100.00

**Source:** Own calculations

The results also show that geographical proximity seems to be important in the establishment of these technological partnerships, since a large share of the projects involve partners in the same municipality and/or district (Table 7): 67% of the technological collaborations involve at least two partners in the same municipality, while in about 37% of the projects all partners are located in the same municipality. Regarding the district, 79% of the technological collaborations involve at least two partners in the same district, while in about 46% of the projects all partners are located in the same district. However, this data equally show that more than half of the RBSOs also relate with organisations *outside the municipality* (63% of the projects have at least one in that case) and even *outside the district* (idem for 54%), suggesting that there may be knowledge circulation beyond the region where they are located. A more detailed analysis of the data will enable us to understand whether these links connect to organisations in the same type of region (i.e. the main metropolitan areas or others), as well as which type of organisations are involved in international relationships.

**Table 7: Proximity of network partners in each project (n=192)**

Partners location	Number	Percentage
At least two in the same municipality	129	67.19
All in the same municipality	70	36.46
At least two in the same district	152	79.17
All in the same district	88	45.83

**Source:** Own calculations



## 5. CONCLUSIONS

This paper presented the results of an analysis of the formal technological relationships established by the population of Portuguese RBSOs, whose goal was to explore the role played by these firms in knowledge networks. In particular, we explored whether RBSOs effectively act as “bridges” between research organisations (in particular the organisation from which they originate) and organisations located downstream in the knowledge value chain; and whether they reach beyond the region where they are located. The results, although still preliminary, already offer some interesting insights and provide some directions for further research.

In what concerns the organizational reach of RBSOs, the results show that, as would be expected, the parent research organisation is an important actor in most firms’ knowledge networks. Moreover, half of the firms only establish formal technological relationships with research organisations, reproducing a frequently depicted pattern among RBSOs. However, the other half has also established relationships with non-academic organisations, and a still substantial number emerge as a central element in tripartite technological relationships. Furthermore, when considering the network formed by the RBSOs and its partners, several spin-offs are found to occupy a position as brokers between the other network actors, potentially facilitating the circulation of knowledge across them. Subsequent research, addressing the evolution of these relationships over the RBSOs life, will investigate whether the structure of the relationships and the position and role of RBSOs changed over time.

In what concerns the spatial reach of RBSOs, the results confirm that they are predominantly located in the main metropolitan areas and, overall, tend to relate with similarly located organisations. Moreover, most firms establish technological relationships with at least some partners located in the same district, or even in the same municipality. But, although a substantial number of firms are exclusively connected with organisations in the vicinity, there are also a number of them that establish technological relationships across municipal or even district boundaries, suggesting a broader network scope. Subsequent research will address in greater detail the composition of these extra-regional networks, in order to understand whether RBSOs are acting as conveyers of knowledge across regions and, in particular, between the metropolitan areas where they are predominantly located and less munificent ones.

Finally, the analysis has focused exclusively on projects funded by national programmes, which usually only encompass national organisations (although a few foreign partners were already identified). However, it is our contention that a full assessment of the role of RBSOs in knowledge networks requires also the consideration of their eventual international

technological relationships (Capaldo et al, 2015). Subsequent research will therefore extend the analysis to include also the projects funded by European programmes.

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**Appendix 1-** Distribution of collaborative projects with RBSOs involvement by Programme

Programmes	Projects with RBSOs			
	N.º	%	First project	Last project
Iniciativa EUREKA	11	05.73	1992	2010
PRAXIS XXI	07	03.65	1997	1999
Projectos Mobilizadores	04	02.08	1997	2007
Iniciativa Comunitária - PME	06	03.13	1999	2000
Iberoeka	04	02.08	2001	2012
I&D em Consórcio	29	15.10	2002	2003
IDEIA - I&D Empresarial Aplicado	31	16.15	2006	2008
Redes de Competência	05	02.60	2006	2006
Programa EUROSTARS	06	03.13	2008	2001
QREN – I&D em Co-Promoção	83	43.23	2008	2012
QREN – Projectos Mobilizadores	06	03.13	2011	2012
	192	100.00		

Source: Own calculations.